

**NATIONAL METAL FINISHING ENVIRONMENTAL R&D PLAN:
AN UPDATE**

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Prepared for

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Submitted by

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Notice

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Foreword

The U.S. Environmental Protection Agency is charged by Congress with protecting the Nation's land, air, and water resources. Under a mandate of national environmental laws, the Agency strives to formulate and implement actions leading to a compatible balance between human activities and the ability of natural systems to support and nurture life. To meet this mandate, EPA's research program is providing data and technical support for solving environmental problems today and building a science knowledge base necessary to manage our ecological resources wisely, understand how pollutants affect our health, and prevent or reduce environmental risks in the future.

The National Risk Management Research Laboratory is the Agency's center for investigation of technological and management approaches for reducing risk from threats to human health and the environment. The focus of the Laboratory's research program is on methods for the prevention and control of pollution to air, land, water and subsurface resources; protection of water quality in public water systems; remediation of contaminated sites and ground water; and prevention and control of indoor air pollution. The goal of this research effort is to catalyze development and implementation of innovative, cost_effective, environmental technologies; develop scientific and engineering information needed by EPA to support regulatory and policy decisions; and provide technical support and information transfer to ensure effective implementation of environmental regulations and strategies.

This publication has been produced as part of the Laboratory's strategic long_term research plan. It is published and made available by EPA's Office of Research and Development to assist the user community and to link researchers with their clients.

E. Timothy Oppelt, Director
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ABSTRACT/EXECUTIVE SUMMARY

This document is an update to the *National Metal Finishing Environmental R&D Plan* (EPA/600/R-97/095), dated September 1997. The 1997 Plan and Update are available on the National Metal Finishing Resource Center's web site, www.nmfrc.org. The primary purpose in preparing an update to the 1997 Plan is to incorporate new information and/or changes that affect the environmental issues facing the metal finishing community. Since the 1997 Plan, there have been changes in regulations relating to the metal finishing industry and changes in technology that have resulted from R&D projects in the past few years. New technology needs have surfaced. There are global and national changes in economies and product demands, and greater concerns for the environment and human health. The 1997 Plan was designed to continuously evolve with the metal finishing industry. This Update is the first attempt to incorporate such changes.

Like the 1997 Plan, the Update focuses on a few of the highest priority R&D areas and concentrates on simple, low-cost, pollution prevention technologies that will be of benefit to the small platers in meeting environmental compliance standards. The recommendations in this Update are based on results from searching the literature for technical progress and regulatory issues. Recommendations also are based on information obtained from selected representatives of the metal finishing industry and other stakeholders who were surveyed to determine if the issues identified in the 1997 Plan are still of concern, and if other issues have become an equal or greater concern. In addition, the American Electroplaters and Surface Finishers Society's (AESF) P2 and Control Committee participated in the final review of this document.

Based upon the findings of this Update, it is recommended that **Nickel** be included as a high priority R&D area. **Technology Transfer** and technical assistance resurfaced as an important item by representatives in the industry. **Hexavalent Chromium, Cyanide, and Cadmium** remained high priority R&D areas, but the emphasis is shifting from emission control and other end of pipe approaches to research, development and demonstration of alternative materials and pollution prevention. **Chlorinated Solvents** require more emphasis on demonstration of alternative materials and information transfer. **Technology Verification Protocol** continues to be a high priority with limited progress to date. **Recycling and Metals Recovery** should be focused more on finding technologies that will be appropriate for small platers. **Emissions and Risk Characterization** R&D has progressed. Past R&D in this area focused on the development of a metal finishing risk assessment tool that will target reduction of risks to workers. The R&D need in this area is shifting to the development of a tool that not only will identify risks to workers and the environment but also will consider cost-effective pollution prevention solutions. It was felt that the 1997 Plan reflected the appropriate R&D focus at the time it was published. However, this R&D Update identifies new issues, updates some issues, and more sharply identifies specific R&D objectives and related project areas.

The *National Metal Finishing Environmental R&D Plan: An Update* should be widely disseminated to the appropriate parties. A surprisingly large portion of those surveyed for this Update, including members of the metal finishing community, as well as representatives from related associations and governments, were either unaware of the 1997 Plan or unfamiliar with its contents. The metal finishing community must be aware of and use this Update to achieve significant benefit. A

National guidance is dependant on the interaction of the stakeholders, and the greater the dissemination of this R&D Update, the greater will be the exchange of information necessary to make good decisions on how to use R&D funding. It is also important for this Update to provide assistance for stakeholders to work “cleaner, cheaper and smarter” in accordance with the Strategic Goals Program (SGP). Information regarding SGP is available via the Internet at www.strategicgoals.org.

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I. INTRODUCTION AND R&D GOALS

A. INTRODUCTION

This document updates the *National Metal Finishing Environmental R&D Plan* (EPA/600/R-97/095) that was published to better focus limited resources on the specific environmental R&D needs of the metal finishing industry, and to meet the industry's strategic goals. The 1997 Plan was developed under the auspices of EPA's Common Sense Initiative (CSI), and it is being used to direct EPA Office of Research and Development metal finishing research. Moreover, preparers of the 1997 Plan hoped to encourage coordination of other public and private sector research in order to fund the highest priority research needs within the metal finishing community.

It was EPA's stated intention for the 1997 Plan to be periodically updated to address economic, technology, and regulatory dynamics. This update is EPA's first revision to the plan to address the R&D progress made and other changes that have occurred since the publication of the original plan in September 1997. This Update emphasizes engineering solutions to research needs driven by compliance issues, R&D funding sources, global industry competition, and current technology. The 1997 Plan was a much needed document in bringing together the R&D needs of the metal finishing community and provided an opportunity for government, academia, industry, and other stakeholders to express their needs and issues. This Update supports the vision of the 1997 Plan by incorporating technical progress since 1997, and by addressing economic and regulatory changes that have affected the metal finishing industry's environmental R&D needs. It verifies the 1997 Plan goals and provides an analysis of the progress and any adjustments that are needed to reach the adjusted goals. It identified several new EPA engineering R&D needs (e.g., development of waste reduction processes, evaluation of control technologies, characterization of emissions) and provides recommendations for priority project areas.

Information used to update the 1997 Plan was gathered from two main sources. Some information related to technical progress and regulatory developments was found through a search of the literature and the internet. Additional and confirmatory information was obtained through discussions with metal finishing industry experts and other stakeholders. The majority of the industry experts who participated in the Update also participated in the 1997 Plan. Information gathering focused on determining if the materials of concern identified in the 1997 Plan as priority research areas are still the materials of highest priority, and if other materials have become an equal or greater concern. This Update attempts to identify the progress made in meeting the specific recommendations of the 1997 Plan; to learn what issues have been resolved; and what new issues, if any, have surfaced.

Three summary criteria were used to provide a simplified rating of the projects described in the R&D Plan. These criteria are: 1) the likely impact of the project in achieving or exceeding compliance requirements, 2) the potential of the project findings to achieve widespread adoption within the industry, and 3) the potential of the project results to reduce risks to workers, the surrounding community, and the environment. This Update used these criteria when ranking the projects recommended in the Recommendations section of this document.

Like the 1997 Plan, this Update focuses on a few of the highest priority R&D areas and concentrates on simple, low-cost, pollution prevention technologies that will be of benefit to the small platers in meeting environmental compliance standards. This approach directly supports the National Metal Finishing Strategic Goals Program (www.strategicgoals.org), the successor to the CSI Metal Finishing Sector. The National Metal Finishing Strategic Goals Program (National SGP) is a cooperative effort between the EPA and the AESF, the National Association of Metal Finishers (NAMF), and the Metal Finishing Suppliers Association (MFSA). The purpose of the National SGP is to “test new ideas” which are both bold and “common sense” in nature for improved environmental protection by the metal finishing industry. The AESF, NAMF, and the MFSA have created an umbrella organization called the Surface Finishing Industry Council, Inc. (SFIC). The SFIC will implement the industry’s participation in the National SGP. The focus of the SFIC is to cooperate with EPA to reinvent the nation’s regulatory system so that it consistently delivers better results for the country while cutting unnecessary costs and red tape. The “Action Plan” from this group addresses research and technology development as a key issue. There are currently 334 metal finishing facilities, as well as 18 state and 55 local regulatory agencies, signed on and committed to the National SGP.

This R&D Plan presents one general recommendation. EPA and other Federal agencies should use this plan to coordinate and support R&D directed toward the needs of the metal finishing industry. This Update confirms that the EPA engineering R&D program is utilizing the 1997 Plan to coordinate efforts and support the metal finishing industry.

The 1997 Plan presented the following eight specific recommendations which are augmented slightly by this Update as discussed in the Recommendations section: (1) **Emissions and Risk Characterization.** Highest priority should be given to developing and applying simple methods to characterize the emissions from plating operations and from them the risks to workers, surrounding communities and the environment. (2) **Hexavalent Chromium.** Highest priority should be given to continuing and expanding R&D on various aspects of reducing and eliminating multi-media emissions from hexavalent chromium plating operations. (3) **Cyanide.** R&D should focus on reducing cyanide emissions and developing improved analytical methods to determine the presence, concentration, and impacts of cyanide in waste streams. (4) **Recycling and Metals Recovery.** High priority should be given to demonstration of off-site recovery methods for metals, acids, and cleaners. (5) **Chlorinated Solvents.** R&D should focus on low emission and emissionless chlorinated solvent vapor degreasing systems for metal plating operations and on evaluating alternatives to chlorinated solvents for cleaning--especially new, alternative cleaners that have recently come on the market. (6) **Technology Verification Protocol.** A Technology Verification Protocol should be developed that would provide information on technology performance, cost, and maintenance requirements on which companies could base decisions to purchase technologies. The published protocol would be made available to interested parties. A process could be set up, perhaps with EPA authorization, to verify protocol results. (7) **Cadmium.** R&D should be carried out to reduce cadmium emissions and to seek alternatives to its use. (8) **Technical Assistance.** Increased technical assistance should be provided to the metal finishing industry through the development and dissemination of a series of short, well-researched, peer-reviewed articles. The focus of these articles should include the selection and use of simple technologies for improved environmental performance for each of the major metal finishing operations that utilize the materials of concern discussed in this

Update.

B. R&D GOALS

The definition of R&D as applied to the needs of the metal finishing industry is incorporated as Appendix A in this Update. The scope of this Update is limited to the definition of metal finishing as encompassed by SIC Code 3471 recognizing that overlap with other industry codes for applying R&D solutions is probable.

The overarching goals of this updated plan are for the results of the R&D to be implemented by the metal finishing industry as part of the effort to reduce the risks to workers, communities, and the environment, and to help the industry become more economically competitive. Reducing the risks to workers, communities, and the environment is a major objective that is specifically addressed in the Plan. Becoming more economically competitive is more a result of activities undertaken in reducing risks such as developing new technologies, optimizing operations, etc.

These overarching goals support those of the National SPG, which are that within 5 years, participating metal finishing firms that enlist in the voluntary program pledge to become:

CLEANER by reducing hazardous emissions

- 90% reduction in organic Toxic Release Inventory (TRI) emissions.
- 50% reduction in metals emissions to air and water.
- 50% reduction in hazardous sludge disposal.
- Substantial reduction in sludge generation.
- Reduced worker and community exposure.

CHEAPER by saving money and providing economic advantages

- 50% reduction in costs of unnecessary reporting, permitting and monitoring.
- Less long-term liability.

SMARTER by conserving resources

- 98% metals utilization on products.
- 50% reduction in water use.
- 25% reduction in energy use.

While the Plan addresses environmental research, energy conservation should be a major consideration in selecting R&D projects for funding.

The main objective of the Plan is to set priorities for near-and long-term environmental R&D for the metal finishing industry. The Plan provides a priority ranking of proposed R&D projects and describes the criteria and approach that were used in making this determination.

Sharing of information among funders and coordinating funding for metal finishing environmental R&D are the next two objectives of the Plan. This sharing of information coupled with better communication regarding R&D needs and progress will lead to producing high-quality R&D, another objective of the Plan.

An objective of the 1997 Plan was to provide a model for other CSI sector subcommittees to consider in developing environmental R&D Plans for their sectors; this Update does not include this objective. The 1997 Plan and Update may be good examples for other sector subcommittees in their efforts to develop environmental R&D Plans, but it is felt that this objective is beyond the control and/or scope of setting a national R&D agenda for the metal finishing industry. The focus of the 1997 Plan and Update should be specifically on the metal finishing industry.

II. R&D NEEDS AND POTENTIAL PROJECTS

The 1997 Plan identified four substances that were of greatest concern from the point of view of toxicity, risk and compliance. These were cadmium, chlorinated solvents, hexavalent chromium, and cyanide. In addition, the following major cross-cutting issues were identified: protocol development, wastewater treatment and recycling, emissions characterization, risk characterization, metal recovery processes, technology assistance, development of a generic life cycle cost model, and development of environmentally friendly strippers.

The 1997 Plan included for each of the four substance areas a background discussion of the item's uses within the metal finishing industry, applicable regulations, recent/current research activities, and a list of possible R&D projects. Discussion of the cross-cutting issues varied according to topic, but followed the same general format. Readers interested in these details can find them on the Internet at www.nmfrc.org.

To update the R&D needs and hence recommended project areas, information was gathered by three primary activities. A literature review was conducted to assess the types of research conducted in recent years and the extent to which this R&D activity reflected recommendations of the 1997 Plan. A regulatory review was conducted to address current and pending compliance issues that might influence R&D choices. Finally, industry and government experts on metal finishing industry environmental issues were interviewed to determine their opinions of the 1997 Plan and their suggestions for additional R&D activities.

A. LITERATURE REVIEW

Substantial R&D activity related to most of the substance and cross-cutting issue areas listed in the 1997 Plan was identified by the literature search. The relative amount of R&D activity identified by the review for each R&D area is indicated in Table 1. Appendix B is a bibliography that can be used to find details on the projects listed in Table 1.

Table 1 lists each of the R&D areas identified in the 1997 Plan, projects being undertaken in each area, and a rating of the R&D project activity found by this update effort. Each of the R&D areas was investigated in developing this Update to determine the related research being conducted since the development of the 1997 Plan. As previously mentioned, this information was gathered by a literature search and discussions with selected metal finishing experts, several of which are listed in the 1997 Plan's Appendix as members of the Research and Technology Work Group, R&D Plan Sub-Group, or respondents to the R&D priority setting effort. Where nine or more related projects were found supporting the R&D area, the R&D activity was rated at "High." Where fewer

TABLE 1. R&D ACTIVITY

R&D Area	Projects Found by Update Effort	R&D Activity Related to 1997 Plan
1. Cadmium	Waste Minimization for Cadmium Plating, Cadmium Replacement, Test Protocol Development, and Life Cycle Costing	Limited
2. Chlorinated Solvents	Aqueous-based and Semi-aqueous Based Alternatives	Limited
3. Hexavalent Chromium	Pollution Prevention for Chromium Plating, Mist Suppressants, Emissions Testing, Performance Evaluation, Fume Suppressants, Chromium Alternatives, and Reduced Chromium Processing	High
4. Cyanide	Non-Cyanide Alternatives/Substitutes, Non-Cyanide -Based Stripping, and Cyanide Recovery	Medium
5. Technology Verification Protocol	DOD/EPA Technology Verification Collaboration (P2 and Waste Treatment)	Limited
6. Wastewater Treatment and Recycling	Integrated Water Recycling, Electrochemical Treatment, In-Situ Generation of Ferric-ions, and Rinse Water Recycle	High
7. Emissions Characterization	Characterization of Air Emissions From Plating Baths for Compliance and Risk	Medium
8. Risk Characterization	Development of Risk Assessment Tool for Metal Finishing Industry, and Risk Screening	Medium
9. Metal Recovery Processes	Evaluation of Membrane Systems and Processes for On-Site Recovery, and Chrome Recovery	Limited
10. Technology Assistance	Conferences, Association Meetings, Symposia, Publications, Articles from industry, NMFRC and from Federal, State, and Local Government Agencies	High
11. Nickel	Electroless Nickel Coatings Measurement, Alkaline Zinc-Nickel Electrolyte, and Emissions	Medium
11. Development of a Generic Life Cycle Cost Model	Life Cycle Assessment Screening Model, Life Cycle Assessment and Electroplating, and LCA Fundamentals	Limited
13. Development of Environmentally Friendly Strippers	Alternative Paint Strippers and Aqueous Cleaning Systems	Limited

than nine but more than three related projects were found supporting the R&D area, and at least one of the projects was significant in size or direct relationship, the R&D activity was rated at “Medium.” A “Limited” activity rating indicates that three or fewer projects were found with direct relationship and/or very little indirect relationship to the R&D area.

As indicated by Table 1, there has been “High” activity in the R&D areas: (1) Hexavalent Chromium, (2) Wastewater Treated and Recycling, and (3) Technical Assistance. Coincidentally, these three R&D areas had the greatest emphasis on pollution prevention.

B. REGULATORY REVIEW

Regulatory developments related to the metal finishing industry were also researched during the literature review. The objective of this effort was not just to identify pending regulations and new legislation at the national and state levels, but to identify R&D initiatives that shape the regulations governing the metal finishing industry and how compliance with regulatory requirements can be achieved. Six major initiatives were identified: (1) the disposal of wastewater treatment sludge; (2) permit application consolidation; (3) Maximum Achievable Control Technology (MACT) Standards; (4) Profitable Pollution Prevention; (5) nickel air emissions; and (6) the European ban on hexavalent chromium products.

The proposed rule to promote metals recovery from wastewater treatment sludge (F006) is an example of the type of regulatory initiative advocated by the SGP. The proposed rule would allow generators of F006 waste up to 270 days to accumulate this waste on-site, so as to improve the economics of recycling this material. F006 generators also would be required to implement on-site pollution prevention strategies and maintain full compliance with all other applicable 90-day on-site accumulation rules.

A SGP-recommended regulatory initiative is being implemented by the Southern California Metal Finishing SGP. This regional organization is developing a consolidated local air and wastewater permit application form for participating metal finishers. The consolidated form will help address the burden of filling out paperwork for various agencies that request the same information. Several drafts of the consolidated application form have been reviewed and a pilot form should be available during the first quarter of 2000.

The U.S. EPA’s 1996 Hard Chrome Pollution Prevention Demonstration Project, provided evidence that fume suppressants can provide highly effective control of air emissions from hard chromium plating baths. As a result of this R&D effort, the MACT Standards were revised to allow the use of fume suppressants as an alternative to more expensive add-on control technologies. This project illustrates the use of pollution prevention to achieve compliance.

Profitable Pollution Prevention (3P) is an approach being embraced within industry to find cost-effective technologies and practices for compliance with the regulations. The 3P approach holds promise for competing globally. Presently, 3P efforts are targeting energy saving measures, material substitutions, process changes, and best management practices. A “lessons learned” technology transfer between government and industry is being encouraged by the NMFRC and U.S.

EPA.

EPA is currently requesting information from the metal finishing industry to help it develop options to minimize the impact of the proposed Metal Products and Machinery (MP&P) effluent guideline rulemaking on small business. There are four areas of current interest:

- Will an exemption for facilities with flows of less than 1,000,000 gallons per year be helpful?
- How much is being spent for analyses of metals, total cyanides, oil and grease, and total suspended solids (TSS).
- EPA estimates that it takes eight hours to complete a Baseline Monitoring Report and two hours each to complete an Industrial User Compliance Attainment Report and a 90-day Compliance Report. EPA would like to know if these estimates are reasonable.
- Is there a surrogate test for oil and grease that is favored by metal finishers?

Another finding from the review of regulatory developments is that Federal regulatory issues are not the only source of influence on metal finishing R&D priorities. Initiatives at both the state/local and international levels are producing significant impacts throughout the industry. For example, the South Coast Air Quality District (SCAQD) in California listed soluble **nickel** salts as a carcinogen in March of 1999. This listing will directly affect nickel platers in the District for the near term and is likely to affect nickel plating operations nationwide in the event similar standards are adopted at the national level.

At the international level, it appears likely that the European Economic Community (EEC) will ban, in 2002, the sale of products manufactured from hexavalent chromium. The 1997 Plan noted that the European ban of **cadmium** products was contributing to development of alternative manufacturing processes and substitute products. It appears likely that the ban on hexavalent chromium products will have a similar impact.

C. EXPERTS SURVEY

Initially, a request for information to update the 1997 Plan was prepared and posted on the web site of the NMFRC (www.nmfrc.org), but no responses were received during the three weeks that it was posted. A calling list of approximately 45 individuals was then developed, using the membership of the CSI Metal Finishing Sector as a starting point.

A total of 14 phone interviews were completed. Several additional respondents indicated they had participated in the CSI Metal Finishing Sector, but were no longer actively involved or up to date with general R&D issues. Respondents included eight representing industry, two from U.S. EPA, and one each from the California EPA, DoD, and academia.

Ten respondents had participated in the original CSI. Half of them said they were familiar with the R&D 1997 Plan and its contents. The other half said they knew about the 1997 Plan but

were not familiar with its general recommendations. All four of the industry representatives who had not participated in the CSI or development of the 1997 Plan were unaware of its existence.

The discussions with the experts always was begun with a summary of some of the initial findings of the literature and regulatory reviews conducted as part of the Update effort followed by an overview of the 1997 Plan recommendations. This introduction created the opportunity to discuss current issues in the context of the R&D prioritization objectives of the 1997 Plan. A summary of the survey results follows.

The largest category of comments from the surveyed experts addressed technology transfer and/or verification protocol issues. The second largest group noted the need for nickel related R&D. Several experts noted progress with respect to toxic metals and chlorinated solvents, with some suggesting a reduced prioritization of these items. Some experts in this group addressed the need to shift R&D focus from control technologies to material substitution technologies, especially with respect to cadmium. Two experts addressed F006 wastes and two suggested research addressing treatment of process water. Finally, there were several comments about the 1997 Plan and a variety of miscellaneous observations. A compilation of interview comments and recommendations is presented in Table 2.

TABLE 2. INTERVIEW COMMENTS

TECHNOLOGY TRANSFER ISSUES
Technology transfer needs to address and correct the information exchange gaps between EPA and the metal finishing industry. The large quantity of existing information needs to be edited for the shop-level users. Information should be available to platers through their local and national associations and through NMFRC, and should be available in summary format with subsequent availability or reference to more detailed information. R&D is needed for the long-term sustainability of the industry, but also to identify and develop information or technology resources to meet the regulatory/economic needs and issues of the shops.
Technology transfer is important to the metal finishing industry. It is best to focus distribution of technical information through state & local metal finishing associations.
A newsletter from the local associations may be the best way for distributing technical information.
R&D projects need to provide easy to use and easy to understand solutions.
Chemical suppliers and Government clients need to be part of the solution with development of less polluting chemicals and options; government should re-evaluate their product specifications to achieve waste and cost reductions.
Platers are looking for down-to-earth technical assistance since most cannot invest time and money on R&D.
Platers need a road map to explain the mission of the national associations, EPA, and states in providing technology support, information transfer and technical assistance.
Metal finishers require much training in the areas of safety, compliance, technical O&M, business and environmental issues. Train-the-trainer packages need to be developed to encourage technological solutions to the finishers' environmental problems.
Customer's specifications are often an impediment to substitution and other P2 options. Product manufacturers and EPA need to work with product users to verify that alternatives are feasible. This suggestion applies to DOD Milspecs, as well as to private industry.
Metal Products and Machinery – need information about how to meet the standards.
Metal finishers need to understand Title V deferrals for Chrome electroplaters, e.g., what will happen after the deferral elapses?
TECHNOLOGY VERIFICATION PROTOCOL
The primary DOD need is to coordinate/focus money and to complete comprehensive demonstration and validation (DemVal) efforts for substitution of aircraft and other critical component applications. DemVal includes fatigue and long-term wear tests. The scale of this effort has forced formation of various tri-service efforts within DOD to identify priorities, focus efforts, and reduce duplication. This is a good improvement in the management of this type of effort.
Technology Verification Process is important; it addresses the need to speed up the research-to-application process. Also, it is important as a means of demonstrating/validating (or refuting) manufacturer's claims and it helps to level the timing and cost of conversion to compliant systems.

TABLE 2 (Continued)

While EPA's Technology Verification Protocol Program is deemed worthwhile, development of the Protocol is deemed too slow.
Pilot demonstrations are needed to prove technologies for application.
NICKEL ISSUES
Nickel is a high priority. South Coast Air Quality Management District has listed soluble nickel salts as a carcinogen. The metal finishing industry needs: (A) independent research to refute or substantiate carcinogenic classification (industry sponsored research refutes), and (B) development of process modifications to minimize exposures to workers and public.
Nickel and nickel emissions are the main priority. Metal finishers need better, cost-effective compliance options.
Nickel is a priority area in California.
TOXIC METALS /CHLORINATED SOLVENTS
Hexavalent Chrome should be at the top of the list for research; especially need to address its use in conversion coatings. The planned European ban on products containing Hexavalent Chrome in 2002 will have a significant impact on the conversion coatings industry. There are no viable alternatives yet, especially for aluminum/chromate coatings for aircraft (alodine, iridite) and for magnesium parts. Also, the impact of this ban is a concern for manufacturers of products by electrodeposits on zinc, tin, copper, and other substances. The Germans are researching and/or marketing trivalent chromium products.
P2 efforts addressing chromium, cadmium, cyanide, and chlorinated solvents have been underway since the late '80s. The primary issues/problems are well recognized, much effort has been done and substantial accomplishments have been achieved, including some material substitutions and nearly complete conversion to aqueous based cleaning.
Control technologies are handling the 'top four' (chromium, cadmium, cyanide, and chlorinated solvents). These areas have been studied for many years and R&D will continue with incremental success.
The priority on cadmium as a research topic should be lowered. Many companies have gone out of cadmium plating business and many replacement coatings have been successfully demonstrated.
Chlorinated solvents are not a major issue. There are many available substitutes, including aqueous systems. Where chlorinated solvents must be used, good technology/equipment is available to minimize air emissions.
Aqueous cleaning is generally applicable as a substitute for solvent cleaning, but there is a need for money, equipment, and industry effort to make it happen.
R&D priority should be given to toxic metals (chromium, cadmium, etc).
There are still a lot of applications for which satisfactory substitute for cadmium or hexavalent chromium. R&D is still needed to find substitutes.

TABLE 2 (Concluded)

F006 RECYCLING
The number one priority from the industry perspective is RCRA F006 wastes. This is a recyclable waste with currently available recycling technologies, but the ability to recycle is constrained by the RCRA categorization of the waste (same wastes from other industrial processes can be recycled because they are not categorically defined as F006). It appears that EPA action has been somewhat slow in dealing with this inconsistency, and EPA appears to have a preference for waste reduction initiatives over recycling alternatives. The plating industry is also interested in waste reduction opportunities, but must recognize the long-term reality of continued production of sludge wastes. Even though waste per pound of product finished or waste per square foot of product finished has gone down, the total quantity of sludge has gone up because business is good.
More money and assistance are needed to demonstrate/validate existing F006 recycling processes and develop new recycling processes.
PROCESS WATER/TREATMENT
R&D is needed to study the use of membrane technologies for recovery of metals and treatment of wastewaters.
Releases of acid mists from plating baths need to be studied. Acid mist releases to the work place and the atmosphere are not well understood.
COMMENTS ABOUT THE 1997 PLAN
<p>Programs stemming from or influenced by recommendations of the 1997 R&D Plan are:</p> <ul style="list-style-type: none"> • Risk Characterization Tool (Point of Contact (POC) is Mat Lorber: 202/564-3223) • ETV – EPA pilot project for metal finishing industry (POC is Alva Daniels: 513/569-7518) • Approaching Zero Discharge (POC is Dave Ferguson: 513/569-7518) • Chicago Goals Project (Adapt Program) • EMS – template development efforts • Green Chemistry Program, EPA Toxics Office
The 1997 Plan was skewed from the beginning, toward risk characterization and there was too much emphasis on individual problems such as Chrome and Chrome Plating.
It is generally agreed that the eight primary recommendations of the R&D 1997 Plan reflect the appropriate R&D focus. No significant additions/deletions are needed.
OTHER
Some attention needs to be paid to the relationship between metal plating plants and surrounding land uses. Is it safe for metal finishing plants to be located in residential neighborhoods?
Some plants should be relocated to address community health issues and improve redevelopment opportunities for the neighborhood (as in Tier III recommendations of the Strategic Goals Program).
Superfund reform – more of the money should be spent on clean up, and less on legal/administrative fees (i.e. Tier III closures).
CSI became a burdensome process to keep up with. There were many meetings and lots of time spent on the phone. EPA compensated some of the travel expenses, but did not compensate for the time. Members could not afford the amount of staff time diverted from priority issues.

III. RECOMMENDATIONS

A. METHODOLOGY

Based on the research conducted to prepare this Update, only minor adjustments to the R&D prioritization recommended in the 1997 R&D Plan is needed. That prioritization was based on the three rating criteria delineated in Section I of this Plan. These criteria are still deemed valid today. Some adjustments to the R&D focus identified in the 1997 R&D Plan are needed to reflect the new environmental issues addressed in Section II of this Update. Others are needed to reflect the activity and progress made on R&D projects recommended in the 1997 Plan. The updated recommended R&D focus is presented below in Section IIIB.

As previously stated, the new R&D prioritization is based on research conducted to prepare this Update. This research included a survey of several experts on metal finishing environmental issues, thus it reflects the opinions of these experts. Notwithstanding this input, the prioritization is the R&D focus deemed by the update authors as the most appropriate for the current environmental issues and availability of tools (e.g., pollution control technology, emissions characterization methodology, etc.) to address these issues.

B. RESEARCH RECOMMENDATIONS

Based on the findings of this Update, environmental R&D for the metal finishing industry should focus on nine areas. These R&D areas are (in descending order of priority):

1. Nickel. Highest priority should be given to developing and applying methods to characterize the emissions from nickel plating operations and to assess the risks of using nickel as an alternative to other metal plating processes. The short-term research for nickel should focus on reducing the releases from nickel plating operations, and the longer-term research on finding alternatives for nickel plating. While there appears to be a shift in plating from cadmium and hexavalent chromium to nickel, this is only a temporary fix. Regulatory issues related to and trade barriers involving nickel will likely arise and dictate the need for additional technical solutions.

2. Hexavalent Chromium. Highest priority should be given to development of alternatives to hexavalent chromium plating other than the use of nickel. High priority should be given to continuing and expanding the R&D on various aspects of reducing and eliminating multi-media emissions from hexavalent chromium plating operations. The focus of the R&D should be on pollution prevention, development of chromium alternatives, and reduced chromium processing. There is a high level of R&D activity in this project area.

3. Technology Transfer. There currently is high technology transfer activity at all levels of government and metal finishing industry. More R&D effort is needed to get information transferred to the targeted end users. Technical information dissemination through the metal finishing associations and states may be the best path to reach the shop operators. There has been a substantial effort by industry and government to make information available electronically and this effort should continue. Any technology information dissemination using newsletters and symposia should

encourage those in the metal finishing community who do not use the internet to begin doing so. This encouragement may be in the form of demonstrations and face-to-face technical assistance. The technology information regarding R&D should focus on the needs of the industry to meet compliance issues, understand products and processes, encourage pollution prevention, and reduce the environmental impacts and human health risks within the facility and community.

4. Technology Verification Protocol. There has been limited R&D in this area and increased priority is needed for a Technology Verification Protocol to be developed and demonstrated in the metal finishing industry. There is a need for decision-makers in the industry to make informed choices based upon the information available on technology performance, cost, risks, compliance, and maintenance requirements. The published protocol would be used by industry practitioners, vendors, consultants, and government to provide an established tool for addressing an environmental problem.

5. On-Site and Off-Site Recovery. There has been limited R&D in this area and more effort should be given to demonstration of methods of on- and off-site recovery. R&D for membrane systems and other technologies and on-site recovery systems should be the focus of this R&D area. Reusing material from rinse water and spent process baths is more difficult for small metal finishers to achieve due to economies of scale and the payback savings may not be attractive. R&D for developing a simple, cost-effective, on-site metals recovery system for small platers can encourage more recycling and resource recovery. Successful technologies to recover metals and salts (evaporation, reverse osmosis, ion exchange, electrolytic recovery, electrodialysis) should be investigated to tailor a system for small platers. There is a need for the development and evaluation of metal recovery from F006 wastes from plating operations.

6. Emissions and Risk Characterization. There has been progress in addressing this R&D need, particularly in the development of a metal finishing risk assessment tool for the metal finishing facility. The need for characterizing emissions from plating operations and finding pollution prevention solutions to reduce the emissions and thereby reduce the risks to workers, the surrounding community, and the environment is a high priority. P2 solutions will reduce control technology compliance needs as well. An emissions and risk characterization procedure to assess the risks will permit the decision-maker to make an informed choice in meeting compliance requirements, reducing risks to workers, and determining the technologies best suited for the operation. A costing protocol should be developed that can be integrated into the decision-making.

7. Cyanide. R&D should continue to focus on reducing cyanide emissions and developing analytical methods to determine the concentration and impacts of cyanide in waste streams. Developing and demonstrating non-cyanide process chemicals should be the focus of R&D efforts related to reducing cyanide emissions. Development of alternatives to cyanide cleaners and plating baths are two recommended R&D project areas. Two criteria that should be applied in the development of alternative non-cyanide processes is that they do not generate wastes that may be more difficult to treat and that they do not generate more sludge than existing cyanide-based processes.

8. Cadmium. R&D to reduce cadmium emissions and to develop alternative non-cadmium

processes should continue. There is activity in this area related to waste minimization, developing test protocols, seeking cadmium replacements, and incorporating life cycle costing into decision-making. Cadmium alternatives for the processes of plating, tumbling, stripping, heat treating and desmutting should be investigated and demonstrated with results made available via technology transfer mechanisms that reach the metal finishers. Cadmium alternatives should reduce releases from the plating baths, drag-out, rinse water, and mists.

9. Chlorinated Solvents. Aqueous and semi-aqueous-based alternatives continue to be the focus for this R&D area. Alternatives to chlorinated solvents are commercially available, but R&D is needed to evaluate and demonstrate the effectiveness of these alternatives. A “consumers report” protocol for selecting the appropriate chlorinated solvent substitute should be developed to help operators/decision makers make informed choices about these alternatives. Case studies and demonstration information transfer is needed to support the integration of chlorinated solvent alternatives into the metal finishing industry.

C. FUTURE OF R&D PLAN

To remain useful, this R&D Plan must evolve with the changes in research needs and the progress on the R&D needs being addressed. As new information on risks is being reported, new regulations are being established, changes in the economy are occurring and new technology is being developed, this Plan will be updated to reflect the priority environmental R&D needs of the industry.

Appendix A

Definition of R&D as Used in This Plan

Appendix A

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The term R&D has a broad meaning as applied to the needs of the metal finishing sector. R&D as used here includes the following components:

Characterizing Emissions and Risks. Platers, environmental groups, community groups, labor, and regulators all need and want to know what emissions are coming out and in what amounts from metal finishing operations and what risks those emissions create for workers, the surrounding communities, and the environment. To answer these questions it is necessary to characterize the inputs to and emissions from the plating operation(s) of concern. Measurement of emission reduction with the associated level of risk, is the best way to evaluate the effectiveness of pollution prevention and control technologies in meeting compliance standards and in going beyond compliance.

Development of New Technologies. New technologies are constantly needed for preventing, recycling, treating, disposing of, and remediating pollution. They are necessary to cost-effectively meet existing and new environmental standards. As used here, new technology means both innovative technologies that enable an entirely new way of doing things and modification of existing technologies for new applications. As a result, the R&D can range from laboratory development to pilot scale testing to field trials of a technology. The intent of this Plan is to weigh more heavily on the applied type of research, although it is recognized that completely new approaches can provide valuable solutions to pollution problems.

Demonstration of Existing Technologies. One of the main problems that small metal finishers face addressing pollution problems in their plants is selecting the best technologies and key vendors. There is currently a paucity of verified testing results on the effectiveness and efficiency of various environmental technologies. Demonstrations are most valuable if they are performed in a working metal finishing operation. Next best is demonstrations using the same, or similar, equipment to that used in actual metal finishing operations, but in a non-operational setting. Providing performance verification through demonstration and evaluation is a high priority for this R&D Plan. The focus should be on evaluation and modification of typical processes so that the results will be as widely applicable to the industry as possible.

Documenting and Optimizing Industrial Operations. The metal finishing industry can be divided into tiers according to the environmental performance of various companies. It is important to document the nature, effectiveness, and cost of the pollution prevention and other environmental management methods that companies use to achieve different levels of environmental performance given the different metal finishing processes that they use. This information can be analyzed and shared

with other companies that want to improve their environmental performance. It is also important to see how existing processes can be optimized to reduce toxic inputs and pollution created.

Developing and/or Applying Tools for Doing R&D. Conducting R&D that will be useful to industry and other users requires tools and techniques that ensure that accurate, reliable, reproducible, and usable data will be developed. In assessing the performance of new and existing technologies, for example, it is necessary to have testing protocols that will meet the highest standards of test plan development and data collection and analysis. Similarly, these high quality procedures are important when collecting baseline performance data for benchmarking purposes. Having agreed-upon analytic tools and procedures for the industry will enable vendors, testers, and users to know how the information they are creating or using fits within a broader set of similar information for the industry.

Transfer of Technology and Diffusion of Technical Information. Because the metal finishing industry is made up of many small companies, it is vital that information about the availability, use, effectiveness, and cost of pollution management technologies be made easily available to these companies. Developing strategies for disseminating the information created as a result of the R&D carried out under this Plan is an essential part of the Plan itself. This information must be presented, packaged, and transmitted in a very user-friendly manner. The transfer should largely take advantage of existing dissemination vehicles and, if possible, allow for interactive question-and-answer mechanisms by the user.

Appendix B

Bibliography for Metal Finishing Research Projects

Appendix B

Bibliography for Metal Finishing Research Projects

1. CADMIUM PROJECTS

Sunthakar, M. "A Waste Minimization in Cadmium & Zinc Plating Using a Zero Waste PVD Method," 20th AESF/EPA Conference (1999).

Waldman, V. "A Cadmium Replacement Through Zinc Alloy Technology: A Customer-Supplier Joined Research Effort," SUR/FIN 96, Session W. (June 1996).

Sunthakar, M. "Waste Minimization in Cadmium & Zinc Plating Using a Zero Waste PVD Method," AESF/EPA Conference, Ft Collins, CO (1999).

2. CHLORINATED SOLVENTS PROJECTS

Pir, R. and D. Roberts. "A Production Testing of Aqueous Cleaning Systems (Record 1 of 3)," 32nd Aerospace/Airlines Plating Forum (1996).

Ferguson, D. *Recycling a Nonionic Aqueous-Based Metal Cleaning Solution with a Ceramic Membrane: Pilot-Scale Evaluation*, U.S. EPA, Cincinnati, OH (1999).

3. CHROMIUM PROJECTS

Grohse, P. and G. Riley. *Review of Chrome Plater Emission Test Methods*, U.S. EPA, Research Triangle Park, NC (January 1999).

Ferguson, D. "Use of Mist Suppressants in Hard Chromium Tanks," 19th AESF/EPA Conference (February 1998).

Mandich, N. "Chemistry & Theory of Chromium Deposition: Part II - Theory of Deposition," *Plating and Surface Finishing* (1997).

"Reducing Hexavalent Chromium Emissions," *Products Finishing* (December 1997).

Koff, J. and N. Stencel. "Evaluation of Performance Capabilities & Operational Requirements of Chromium Purification Technologies," 16th AESF/EPA Pollution Prevention and Control Conference (February 1995).

Ferguson, D., B. Sprague, D. Brennan, and J. Lutz. "Use of Fume Suppressant in Hard Chrome Baths – Emission Testing," AESF/EPA Conference, Ann Arbor, MI (1999).

Ferguson, D., M. Zellen, D. Brennan, and J. Lutz. "Use of Fume Suppressant in Hard Chrome Baths - Quality Testing," AESF/EPA Conference (1999).

Klingenberg, M., B. Manty, and D. Schario. "Chromium Alternatives Update," AESF/EPA Conference (1999).

Sartwell, B., K. Legg, and B. Bodger. "HVOF Thermal Spray Coatings as an Alternative to Hard Chrome Plating on Military and Commercial Aircraft," AESF/EPA Conference (1999).

Kovacs, W. "An Alternate Wear Treatment to Replace Chrome Plating," AESF/EPA Conference (1999).

Mason, S. "Case Study: Zero Sewer Discharge for a Hard Chrome Plating Facility," AESF/EPA Conference (1999).

Renz, R., T. Schumaker, J. Sun, J. Chromick, B. Grant, E. Taylor, P. Miller, and C. Zhou. "In-process Recycling of a Hexavalent Chromium Plating Bath," AESF/EPA Conference (1999).

Hansen, P. and M. Gage. "Treatment of Hexavalent Chromium in Groundwater Using Ion Exchange: Development of Remedial Technology," AESF/EPA Conference (1999).

Naguy, T., M. Klingenberg, M. Pavlik, and D. Schario. "Non-line-of-sight Hard Chromium Alternatives," AESF/EPA 2000 Conference for Environmental Excellence.

Hui, W. "A New Ni-Fe-Co Alloy Substitute for Chromium Plating," AESF/EPA 2000 Conference for Environmental Excellence.

Flanigan, M. and B. Vandivier. "A New Alternative for Decorative Hexavalent Chromium Plating," AESF/EPA 2000 Conference for Environmental Excellence.

Legg, K. and B. Sartwell. "Hard Chrome Alternatives Team Update – Improving Performance While Reducing Cost," AESF/EPA 2000 Conference for Environmental Excellence.

Ferguson, D. *Capsule Report - Hard Chrome Fume Suppressants and Control Technologies*, EPA/625/R-98/002 (December 1998).

Renz, R., P. Miller, E. Taylor, C. Zhou, and R. Richardson. "Validation of a Functional Trivalent Chromium Plating Process," AESF/EPA 2000 Conference for Environmental Excellence.

Schario, D., M. Pavlik, M. Klingenberg, and E. Brooman. "Corrosion Performance of Environmentally Acceptable Alternatives to Chromium Coatings," AESF/EPA 2000 Conference for Environmental Excellence.

Lee, B. and S. Koelzer. "Vacuum Deposition of Chromium as an Alternative to Hexavalent or Trivalent Chromium Plating," AESF/EPA 2000 Conference for Environmental Excellence.

Renz, R., C. Zhou, E. Taylor, E. Stortz, and B. Grant. "Functional Chromium Plating from a Trivalent Chromium Bath," AESF/EPA Conference (1997).

Legg, K., M. Graham, and T. Bernecki. "Applications for Chromium Plating Alternatives: Repair Technology & OEM Coatings," AESF/EPA Conference (1997).

El-Sharif, M. "Environmental Gains in High-speed Chromium Plating from Chromium (III) Electrolytes Using Advanced Process Technology," AESF/EPA Conference (1997).

Lord, J. "Effect of Pollution Prevention on the Functional Properties of Hard Chrome Plate," AESF/EPA Pollution Prevention & Control Conference (1998).

Ferguson, D. *Membrane Electrolisis Demonstration for Hard Chrome Plating Bath Regeneration – Research in Progress*, U.S. EPA, Cincinnati, OH (February 2000).

4. CYANIDE PROJECTS

Morrissey, R. and D. Pacheco. "Materials Characterization of a Non-Cyanide Silver Electrodeposit," *Painting and Surface Finishing* (December 1997).

Fedkiw, D. & P. Fedkiw. "A Model of Copper Electrodeposition from Cyanide Electrolyte. Part II-Current Distribution on a Disk Electrode (AESF Research Project #91)," SUR/FIN 97 Conference (June 1997).

Packman, S. "A Plater's Lament: "They're Taking My Cyanide Away. A Case Study of the Implementation of Non-Cyanide Silver in a Production Plant," 15th AESF/EPA Conference, Session 4 (1994).

Grosse, D. *Managing Cyanide in Metal Finishing, U.S. EPA Capsule Report*, U.S. EPA, Research Triangle Park, NC (April 1999).

5. TECHNOLOGY VERIFICATION PROTOCOL DEVELOPMENT

Voytko, J. and A. Daniels. "Environmental Technologies Verification for Metal Finishing," AESF/EPA Conference (1999).

Daniels, A., E. Voytko, and D. Brown. "Environmental Technology Verification for Metal Finishing," AESF/EPA 2000 Conference for Environmental Excellence.

6. WASTEWATER TREATMENT & RECYCLING PROJECTS

Lou, H., Y. Yang, and Y. Huang. "Design of a Wastewater Reuse Network for Electroplating Processes," AESF/EPA Conference (1999).

Laurin, M. "Innovative Chromium-bearing Waste Recycling Technology," AESF/EPA Conference (1999).

Sendrey, G. "Case Study: Integrated Water Recycling System for Semiconductor Manufacturer Reduces Consumption by 15.8 Million Gallons/Yr.," AESF/EPA 2000 Conference for Environmental Excellence.

Allan, G. and C. Babb. "Rinsewater Recycle Design & Operations," AESF/EPA 2000 Conference for Environmental Excellence.

Renz, R., P. Miller, E. Taylor, and C. Zhou. "In-Process Purification of Plating Baths," AESF/EPA 2000 Conference for Environmental Excellence.

Kniazewycz, B. and C. Lemon. "3-D Electrolytic Cell Provides New Option for Wastewater Recycle & Waste Minimization," AESF/EPA 2000 Conference for Environmental Excellence.

Borst, P. "Recycling Wastewater Treatment Sludges from Electroplating Operations, F006," AESF/EPA Conference (1997).

Riley, C. "Process Wastewater Reuse: Making It Happen," AESF/EPA Pollution Prevention & Control Conference (1998).

White, G. "Closed-loop Rinsewater Recycling vs. Once-through Water Usage & Discharge (An Analysis of Operating Costs)," AESF/EPA Pollution Prevention & Control Conference (1998).

Burford, R. "Closed Loop Plating Systems That Recover Rinse Waters & Improve Rinsing," AESF/EPA Pollution Prevention & Control Conference (1998).

Renz, R., T. Fritchley, J. Sun, E. Taylor, and C. Zhou. "In-process Recycling of Plating Rinsewater for PWB Operations Using an Electrochange Recovery System," AESF/EPA Pollution Prevention & Control Conference (1998).

Reinhard, F. "Water Purification & Recovery Technologies – A Critical Review," AESF/EPA Conference (1999).

Williams, M. and D. Vogel. "Reducing Operating Costs & Waste Using Electrodialysis to Regenerate Electroless Nickel Baths," AESF/EPA Conference (1999).

Renz, R., T. Schumaker, J. Chromick, B. Grant, E. Taylor, P. Miller, J. Sun, and C. Zhou. "In-process Recycling of a Spent Electroless Nickel Plating Bath," AESF/EPA Conference (1999).

Brown, S. "Controlled Atmosphere Separation Technology Recovery of Wastewater & Process Chemistries in Metal Finishing & Electronic Applications," AESF/EPA Conference (1999).

7. EMISSIONS CHARACTERIZATION

Tobin, J. "Estimating Chemical Air Emissions from Solutions in Process Tanks at a Plating Jobshop Using a Timely & Inexpensive Method," AESF/EPA 2000 Conference for Environmental Excellence.

Lord, J. "Air Emission Factors for Selected Plating Processes," AESF/EPA Conference (1997).

Hensley, J. "Air Emission Pollution Prevention Technologies Used in the NIST-MEP/EPA-CSI Hard Chromium Demonstration Project to Meet the 1995 Chromium MACT Standard," AESF/EPA Conference (1997).

Miles, T. "Ratio of Hexavalent to Total Chromium in Stack Testing – A Gauge of Control Efficiency?" AESF/EPA Conference (1999).

Fraiser, M., T. Panagiotou, A. Hunter, and J. Hay. "Fugitive Emissions Reduction & Measurement Above a Hard Chromium Plating Tank," AESF/EPA Conference (1999).

8. RISK CHARACTERIZATION

Lorber, M and P. Shapiro. "A Risk Assessment Tool for the Metal Finishing Industry," 20th AESF/EPA Conference (February 1999).

Farag, I., D. Peavey, and W. Waugh. "Assessing Chemical Risk in the Absence of Data: Prevention Assessment Framework," AESF/EPA Conference (1999).

Lorber, M., P. Shapiro, G. Schweer, S. Schwartz, C. Peck, and D. Bottimore. "EPA's Metal Finishing Facility Risk Screening Tool (MFFRST): Part 1, Status & Update," AESF/EPA 2000 Conference for Environmental Excellence.

Schwartz, S. and M. Lorber. "EPA's Metal Finishing Facility Risk Screening Tool (MFFRST): Part2, Updates to Sources Emission Characterization," AESF/EPA 2000 Conference for Environmental Excellence.

Farag, I., D. Peavey, and L. Wallace. "Risk Assessment Tool in the Metal Finishing Industry," AESF/EPA Pollution Prevention & Control Conference (1998).

9. METALS RECOVERY PROCESSES

Ho, W., T. Poddar, R. Ousic, and J. Roller. "Unique Membrane Technology for Removal/Recovery of Metals from Wastewaters & Process Streams," AESF/EPA Conference (1999).

Werner, T., R. Litt, S. Chauhan, and B. Monzyk. "Hexavalent Chrome Recovery from Wastewater," AESF/EPA Conference (1999).

Volle, N. "Metal Recovery & Cyanide Destruction by Electrolysis," AESF/EPA Pollution Prevention & Control Conference (1998).

10. TECHNICAL ASSISTANCE PROJECTS

Groom, R. "Helpful Advice for Finishing Companies: Use the SFMRB Reports to Meet ISO Certification Requirements," *Plating and Surface Finishing* (March 1999).

Gong, J., K. Luo, and Y. Huang. "Process Optimization & Pollution Prevention via OP2EP-Advisor, (AESF Research # 96)," SUR/FIN Conference (June1997).

Ferguson, D. *Technology Demo Program: Approaching Zero Discharge in Metal Plating and Finishing*, U. S. EPA, Cincinnati, OH (1999).

Hankinson, K., T. Brady, and A. Chmielewski. "Energy Conservation & Process Control Utilizing Covered Tanks," AESF/EPA Conference (1999).

Eskamani, G. "Approaching Zero Discharge (AZD) Project-Progress Review," AESF/EPA

Conference (1999).

Bloch, L., M. Keefe, and J. Siemak. "Merit Partnership Pollution Prevention Project for Metal Finishers," AESF/EPA Pollution Prevention & Control Conference (1998).

Bloch, L., M. Keefe, T. Adkisson, and J. Siemak. "Pollution Prevention Implementation Under the Merit Partnership Pollution Prevention Project for Metal Finishers," AESF/EPA Pollution Prevention & Control Conference (1997).

Bloch, L., M. Keefe, and P. Wooliever "EMS Template for Metal Finishers: EMS Implementation at Several Southern California Sites," AESF/EPA 2000 Conference for Environmental Excellence.

11. NICKEL EXPOSURE DATA COLLECTION

Das-D-Chin, L., G. Evarts, and R. Zeller III. "Electrochemical Porosity Measurement of Electroless Nickel Coatings on Ferrous Substrates Information Resulting from AESF Research Project," *Plating and Surface Finishing* (July 1997).

Roev, V. and R. Kaidrikov. "A New Alkaline Zinc-Nickel Electrolyte," SUR/FIN Conference (June 1997).

High, M. "MFASC-SCAQMD Nickel Electroplating Emissions & Control Technology Study," AESF/EPA 2000 Conference for Environmental Excellence.

Bless, D. "A Review of Nickel Plating Bath Life Extension, Nickel Recovery & Copper Recovery from Nickel Baths," AESF/EPA 2000 Conference for Environmental Excellence.

12. DEVELOP GENERIC LIFE CYCLE COST MODEL

Bates, W., J. O'Shaughnessy, and S. Johnson. "Development of a Life Cycle Assessment Screening Model," AESF/EPA Conference (1999).

Jensen, A. "Life Cycle Assessment & Electroplating," AESF/EPA Conference (1999).

Bates, W. "How to Use a Life Cycle Assessment to Its Fullest: The Fundamentals," AESF/EPA 2000 Conference for Environmental Excellence.

13. DEVELOP ENVIRONMENTALLY FRIENDLY STRIPPERS

Young, W., K. Cramer, D. Speer, and S. Guthrie. "Alternative Paint Strippers to Methylene Chloride," AESF/EPA Conference (1997).

Pirrotta, R. "Production Testing of Aqueous Cleaning Systems," AESF/EPA Conference (1997).